



# **Closeout Report on the DOE/SC Review of the**

## **LHC CMS Detector Upgrade Project**

**Fermi National Accelerator Laboratory**

**October 14-15, 2015**

**Kurt Fisher**

**Committee Chair**

**Office of Science, U.S. Department of Energy**

<http://www.science.doe.gov/opa/>



# Review Committee Participants

## Kurt Fisher, DOE/SC, Chairperson

### SC1

#### HCal—Hadron Calorimeter (WBS 1.2)

- \* Tom LeCompte, ANL
- Jim Pilcher, U of Chicago

### SC2

#### Forward Pixel Detector (WBS 1.3)

- \* Jim Brau, Oregon (first day only)
- Leo Greiner, LBNL

### SC3

#### Level 1 Trigger (WBS 1.4)

- \* Charlie Young, SLAC
- Kevin Pitts, U of Illinois

### SC4

#### Cost and Schedule

- \* Frank Gines, DOE/ASO
- Penka Novakova, BNL
- Ray Won, DOE/OPA

### SC5

#### Project Management (WBS 1.1)

- \* Jon Kotcher, BNL
- Mark Palmer, FNAL

### Observers

Jim Siegrist, DOE/SC  
Mike Procario, DOE/SC  
Simona Rolli, DOE/SC  
Alan Harris, DOE/FSO  
Pepin Carolan, DOE/FSO  
Mark Coles, NSF

### LEGEND

SC Subcommittee  
\* Chairperson

**Count: 12 (excluding observers)**



1. Management: Is the management structure and resources adequate to deliver the proposed technical scope within stated performance by CD-4, both overall and from the point of view of individual DOE and NSF awardees?
2. Estimate to Complete: Is the Estimate to Complete updated and credible? Are the proposed annual goals and performance metrics for the current year suitable as effective indicators of performance in the coming year?
3. Cost and Schedule: Are the current project cost and schedule projections consistent with the approved baseline cost and schedule? Are the technical and financial status of the project accurately represented in the most recent monthly reports, reflecting project milestone status, EVM, risk and contingency management, configuration management and change control board actions, EH&S, and discussion of any other issues relevant to project performance from the point of view of awardees and sub-awardees?
4. Risk: Has the risk analysis been updated to accurately reflect the risks that remain in completing the project? Is the contingency still adequate for the risks? Are there any significant risks that jeopardize CD-4 completion and require high level management attention?



2. Estimate to Complete: Is the Estimate to Complete updated and credible? Are the proposed annual goals and performance metrics for the current year suitable as effective indicators of performance in the coming year? .

*The Estimate to Complete is up-to-date and reasonable. The milestones appear to be adequate to track project performance.*

4. Risk: Has the risk analysis been updated to accurately reflect the risks that remain in completing the project? Is the contingency still adequate for the risks? Are there any significant risks that jeopardize CD-4 completion and require high level management attention? .

*The risks are regularly monitored. There remain risks to cost, schedule and the phasing of performance, but none of these are of sufficient magnitude to jeopardize CD-4.*



- **Findings**

This project has three subprojects: replacing the HF Front-end electronics, replacing the HE and HB front-ends, including photosensors, and replacing the HCAL counting room electronics. The project is scheduled so that necessary detector access occurs during the next technical stop (the 2016 Year End Technical Stop] for the HF, the extended technical stop for the HE and Long Shutdown 2 for the HB.

A key element for multiple subprojects is the VTTx optical links, produced at CERN. While some units have been delivered, the earliest possible date for bulk delivery is now the end of October, which is close to the need-by date to meet this schedule.

- **Comments**

- **Recommendations**



- **Comments**

The schedule is driven by the needs of the CMS experiment, and the desire to both spread out the installation work in the cavern and to provide CMS the best possible instrument on the earliest timescale. Meeting this schedule will automatically meet the CD-4 milestone well before the schedule.

The complete HF work will not be possible in the upcoming shutdown, because [international] CMS management does not believe the PMT Box can be reworked in this window. In addition, the late VTTx delivery schedule from CERN makes it likely that other tasks will slip as well. This will have knock-on effects, such as delaying and shortening the time for system integration. None of this puts CD-4 at risk, and even in the worst case, all three subtasks can complete their installation during LS-2.

Should the VTTx delivery slip again, the Hadron Calorimeter schedule will be substantially impacted. US CMS management should continue to work with CERN to avoid this. If this becomes unavoidable, the new schedule will likely have later component installation.

Subproject management makes good use of Project Management tools and has used and is using them to actively manage the project and not merely as a report-writing tool.



- **Recommendations**

None



**2. Estimate to Complete:**

**Is the Estimate to Complete updated and credible? YES**

**Are the proposed annual goals and performance metrics for the current year suitable as effective indicators of performance in the coming year? YES**

**4. Risk:**

**Has the risk analysis been updated to accurately reflect the risks that remain in completing the project? YES**

**Is the contingency still adequate for the risks? YES**

**Are there any significant risks that jeopardize CD-4 completion and require high level management attention? NO**





## Findings

- The target of the FPIX project is to complete the construction of the FPIX hardware to be installed at CERN in January 2017 during the Extended Technical Stop.
- The FPIX pilot detector consisting of 8 modules installed in CMS with the current pixel detector revealed a serious jitter issue that the team has worked to overcome. This has resulted in delays in port card production and a new Token Bit Manager (TBM) fabrication. In addition testing of the TBM has been extended.
- The yield of the High Density Interconnects is low from the existing vendor. Alternate vendors have been solicited and batches ordered for qualification. This remains a schedule risk, nevertheless it is expected that the HDI production rate can be brought to necessary levels using alternate vendors. The next batch from the first vendor is due in late October. The timescale of the alternate vendors including HDI qualification is longer.
- There are delays in the fabrication of the module and system components that show a shift of approximately 3 months in the availability of a first production full module/electronics chain. This delay is mitigated by the incorporation of a faster production throughput that should, if realized, allow the delivery to meet the schedule. The first half cylinder is now expected to be completed in December.



### Findings

- The yields of the readout chips and other custom ASICS already fabricated as well as the flip chip assembly process appear to be sufficient to meet the required number of assembled modules and half disks assuming the presented yield expectations.
- The mechanics budget has increased by \$500k. This is attributed to a known under-estimate that was not propagated into the baseline cost and schedule documentation as estimates were not yet available. After the new work was added to the Baseline through Baseline Change Control, the mechanics has been performing to the new schedule.
- The FPIX project critical path now runs through the modules/electronics rather than through the mechanics, as was the case during CD-2/3 review. This is the case, even though the mechanics themselves have been lagging behind schedule.
- There is 3 months of reported float between the FPIX scheduled completion and the CERN “need by” date in the optimistic scenario. The realistic scenario shows only one month. There are opportunities for improvement as the electronics issues are resolved.
- The available contingency, based on the analysis presented, appears to be sufficient to complete the FPIX project successfully, if the delays which have been experienced so far do not continue.



### Comments

- Near term level 4 and 5 milestones are mostly shown as late by a few months. This is explained as both out of order fabrication (as measured by the existing baseline) and real delays. The schedule and build rates as presented shows that there is time to meet the delivery date. This new plan should be monitored carefully as it pushes important system integration milestones later into the schedule where there is less time to deal with any problems that arise.
- The production of High Density Interconnects (HDI) has experienced a low yield. Recent improvements in yield are encouraging. This is now a critical component in the schedule. The FPIX team has focused attention on strategies to deal with this problem including the enlistment of multiple vendors.
- The presented plan to produce 5 full half cylinders is very likely to allow for the successful completion of the FPIX Objective KPP, however completion in time for the installation during the extended technical stop is less certain. Additional electronics engineering may help alleviate this concern.
- The lack of spare mechanical components in the current plan provide little capability to respond to mechanical failures that could result in significant schedule delay.
- The estimate to complete has been updated to reflect the findings above and appears to be complete and credible.



### Comments

- The BCRs that are planned appear to be reasonable and fit with the newly presented plan for meeting the delivery schedule.
- The risks appear to have been properly assessed and mitigation plans are in place.
- The bump bonding contract has been delayed due to issues in contract arrangements. This should be resolved as soon as possible. The critical path runs through the module assembly.
- It appears that there may be some flexibility in the scheduling of the extended technical stop. The project may wish to coordinate with the Barrel pixels and CMS and CERN management to provide schedule adjustments if necessary and possible.



### Recommendations:

- The FPIX sub-project should proceed urgently with multiple HDI vendor procurement.
- The FPIX sub-project should proceed with the fabrication of an increased number of spare mechanical components.
- The FPIX sub-project should increase engineering resources dedicated to the electronics.



2. Estimate to Complete: Is the Estimate to Complete updated and credible? Are the proposed annual goals and performance metrics for the current year suitable as effective indicators of performance in the coming year?

*Yes.*

4. Risk: Has the risk analysis been updated to accurately reflect the risks that remain in completing the project? Is the contingency still adequate for the risks? Are there any significant risks that jeopardize CD-4 completion and require high level management attention?

*Risk analysis has been updated. Also see comments.*

*Contingency is adequate.*

*No significant risks.*

- **Findings**
- **Comments**
- **Recommendations**



- **Findings**

- Physics motivation for the L1T upgrade continues to be strong
- Hardware production largely complete
- Significant progress on firmware and software
- In-situ tests of vertical slices in parallel with legacy system
- Interconnect, throughput and algorithm tests confirm design expectations

- **Comments**

- Impressive progress in the last year, and project in excellent shape overall
- Update risk registry, as planned, to include MTF7 board from 1st production run
- Continue monitoring remaining firmware and software tasks

- **Recommendations**

- None



2. Estimate to Complete: Is the Estimate to Complete updated and credible? Are the proposed annual goals and performance metrics for the current year suitable as effective indicators of performance in the coming year?
  - ETC updated and credible – **YES**. Monthly EAC Analysis are provided; the most recent dated Aug 2015 which concluded that the difference between EAC and BAC is less than 1% which indicates that the total cost should not surpass the total funding.
  - Annual goals & performance metrics suitable – **YES**. Each CAM has a clear understanding of their subsystem scope and has defined goals and metrics.
  
3. Cost and Schedule: Are the current project cost and schedule projections consistent with the approved baseline cost and schedule? Are the technical and financial status of the project accurately represented in the most recent monthly reports, reflecting project milestone status, EVM, risk and contingency management, configuration management and change control board actions, EH&S, and discussion of any other issues relevant to project performance from the point of view of awardees and sub-awardees?
  - Current cost & schedule consistence with the baseline? – **YES**. But, the PEP should be revised to reflect the current OPC & TEC distribution.
  - Is financial status accurately reported? – **YES**. The program office receives a tailored monthly report with focused coverage.





4. Risk: Has the risk analysis been updated to accurately reflect the risks that remain in completing the project? Is the contingency still adequate for the risks? Are there any significant risks that jeopardize CD-4 completion and require high level management attention?
- Risk analysis updated & accurately reflects remaining risks? – **YES**. The project has an effective & detailed risk mgmt. process.
  - Is contingency adequate for the risks? – **YES**. Based on Monte Carlo simulations, the cost and schedule contingencies are adequate for the known risks.
  - Any significant risks that jeopardize CD-4? – **NO**. None of the current risks drive the technical completion or CD-4 dates.



- **Findings**

- Resource Loaded Schedule has 3727 activities and 613 milestones. In FY15 half of the project tasks and a third of the milestones were completed.
- The Responsibility Assignment Matrix (RAM) consist of 10 Control Account Managers (CAMs) responsible for 14 control accounts.
- Work Authorization Documents that formalize the CAM's scope of work and resources are issued to each CAM.
- The monthly monitoring output consist of a details monthly report, EVM report (CPR1), and EAC Analysis.
- Project activities are status each month by the CAMs and L2 system managers using a standardized turn-around report.
- Variance Analysis Reports are produced for control accounts that exceed established higher level threshold limits, and describe variance, impact, and corrective action.
- Change requests are being managed. To date, 85 BCRs have been process (approved or rejected), 37 BCRs processed since the CD-2/3 ESAAB.
- An EVMS Surveillance Review was conducted in Dec 2014 as part of the recertification of Fermilab's system.



- **Findings**

- The project has reset the practice baseline at CD-2/3 approval to aligned BCWS, BCWP and ACWP. The SPA-reset action was documented in BCR 57.
- About \$1M of contingency has been used since change control inception on \$17.7M (51% of project completion). About \$5.77M of contingency remains on \$12M of cost to go.
- Key project management documents available for this review include: Responsibility Assignment Matrix (RAM), Work Authorization Documents (WADs), Contract Performance Report (CPR) Format 1, Variance Analysis Reports (VARs).
- The monthly report covers project milestone status, EVM, contingency management, configuration management and change control board actions, and discussion of any other issues relevant to project performance.
- Since CD-2/3 baseline, there were 7 opportunities realized and 4 retired, and there were 9 threats managed and 24 retired. The current risk registry consists of 35 threats (7 ranked high) and 12 opportunities.
- The current total cost contingency for all risks is \$1,181K at 90% C.L.; in Aug 2015 the DOE contingency is \$5,773K. The estimated finish date at 90% C.L. is Feb 2019 or 10 months to CD-4.
  - 90% C.L. is conservative but it's standard Fermilab practice for covering risk.



- **Comments**

- The TEC cost presented during the review is \$286K higher than the recorded TEC cost in the PEP as a result of some activities being re-planned due to the FY15 continuing resolution. The revised OPC/TEC cost distribution needs to be corrected in the PEP.
- The contingency log list all change requests and their impact (increase/decrease) on contingency. This is an appropriate way to track the use of cost contingency.
- The team is knowledgeable and the CAMs have ownership of their schedules. The system managers are familiar with concepts of early completion date and schedule contingency.
- There are 10 months of schedule contingency to CD-4. Float can be increased by additional 5 months if the Objective KPP for HCAL is dropped from the project plan.
- It is clear the Project Manager and the IPT are paying close attention to the earned value measurements and taking corrective actions when needed. Estimate at Complete (EAC) is part of the monthly reporting to DOE.
- The Project Manager conducts an EAC Analysis on a monthly basis. VARs are detailed and provide useful information to project team. The Corrective Action Log tracks all corrective actions to closure.



- **Comments**
  - In Aug 2015 the cumulative schedule variance of FPIX (401.03.03.02, Component-Electronics) is -16% and concerning. However, the team is confident that the completion of the detector will not be affected.
  - Minor data inconsistency exist between the information provided to the committee and the Aug 2015 monthly report, which should be reconciled.
- **Recommendations**
  - The revised OPC/TEC distribution needs to be corrected in the PEP by the end of Q1/FY16.



### 3. Cost and Schedule

F. Gines, P. Novakova, R. Won  
Subcommittee 4

<b>PROJECT STATUS (as of Aug 2015)</b>		
Project Type	MIE / Line Item / Cooperative Agreement	
CD-1	Planned: 10/18/2013	Actual: 10/17/2013
CD-2	Planned: 11/12/2014	Actual: 11/12/2014
CD-3	Planned: 11/13/2014	Actual: 11/12/2014
CD-4	Planned: 12/30/2019	Actual:
TPC Percent Complete	Planned: <u>58.8</u> %	Actual: <u>55.4</u> %
TPC Cost to Date - as of Aug 2015	\$ 15,069K	
TPC Committed to Date	\$ 16,003K	
TPC	\$ 33,217K	
TEC [OPC & TEC was revised post-CD2/3]	\$ 21,516K	
Contingency Cost (w/Mgmt Reserve)	\$ 5,773K	<u>48.1</u> % to go
Contingency Schedule on CD-4b	<u>10</u> months	<u>19.2</u> %
CPI Cumulative	0.99	
SPI Cumulative	0.94	



1. Management: Is the management structure and resources adequate to deliver the proposed technical scope within stated performance by CD-4, both overall and from the point of view of individual DOE and NSF awardees? **YES**
2. Estimate to Complete: Is the Estimate to Complete updated and credible?  
**YES**  
Are the proposed annual goals and performance metrics for the current year suitable as effective indicators of performance in the coming year?  
**YES**
4. Risk: Has the risk analysis been updated to accurately reflect the risks that remain in completing the project? **YES**  
Is the contingency still adequate for the risks? **YES**  
Are there any significant risks that jeopardize CD-4 completion and require high level management attention? **NO**



- **Findings**
- Regular meetings are being held, including weekly internal technical meetings, PMG and POG meeting with the Laboratory, and IPT meetings.
- CPI in all areas of the project is running very near 1. The SPI, on the other hand, is noticeably  $<1$  in several cases.
- The management team is fully staffed.
  - Robust transition plans were described where staff replacements required.
  - New management staff were added where critical path efforts required further support (i.e., FPIX Assembly & Testing).
- A risk management process was presented. No single remaining identified risk has the potential to fully draw down the project contingency.





- **Comments**
- The project has been making excellent progress since CD-2/3, and its progress and status is well quantified and traceable, and on track for CD-4.
  - Detailed CPI and SPI tracking of individual sub-projects appear very reasonable for this stage in the project.
  - Where specific challenges exist, the individual sub-projects are pursuing mitigation strategies and executing a well defined BCR process, as necessary.
  - The RC to ETC ratio appears very robust. A sufficient amount of project contingency remains that should take them through project completion.
  - There is now room in the budget to more aggressively approach contingency to both ensure timely project completion, and to work to optimize overall CMS physics output.
- The schedule for each of the subsystems appears robust, with no sizable outstanding issues inhibiting project completion to CD-4.
- The necessary resources appear to be available to successfully execute the project through CD-4.
- Project tools are being used extensively and to advantage to monitor and evaluate project progress, and, where possible, to anticipate problems that might arise. The tools are being embraced by the L2-L3 managers and CAMs.



- **Comments (cont'd)**
- Meetings internal to the project, and with the Laboratory and the agencies, are held with appropriate frequency and regularity to facilitate project progress, and to obtain input and/or address issues that might require broader discussion.
- Project risks appear to be under control and active risks are being effectively managed.
  - The risk assessment is being maintained to reflect the current project status, and no risks are apparent which could seriously jeopardize any of the Threshold KPPs for the project.
  - Where specific risk threats have been realized, the relevant managers have aggressively worked the problem and suitable BCRs have been processed
- The interdependence of the NSF and DOE deliverables is well understood, and being appropriately managed.
- The project is being managed with close attention paid to the requirements of each agency. The management of the NSF Cooperative Agreement and the subcontracts with the NSF awardees are being well managed and properly tracked.



- **Comments (cont'd)**
- The project is to be commended for having created a culture of open communication, both internally and with all the relevant stakeholders, including the Laboratory and the agencies. This is a notable feature of the project, and a significant component of its success to date.
- The project team – managers at all levels, CAMs, technical personnel -- is strong, highly engaged, and well integrated, and demonstrates a keen commitment to the US CMS Phase I project and its successful execution.
- The Laboratory demonstrates an appropriately strong level of support of, and engagement with, the project and its needs for successful completion.
- The Project Manager is fully engaging the entire management team in the project management and tracking tools. The Laboratory has provided an effective means of implementing its project tools that enables the project management team.



- **Comments (cont'd)**
- While it does not influence overall project completion and CD-4, the project team should consider sharpening its planning to help ensure that the FPIX schedule is maintained, and to enhance the probability of its timely completion by the CERN need-by date. This might include generating a more detailed staffing plan that focuses on the FPIX production end game, and the anticipatory use of contingency up front to develop a complementary technical labor pool with the appropriate expertise.
- **Recommendations**
- Continue to explore options for accelerating delivery of the FPIX.